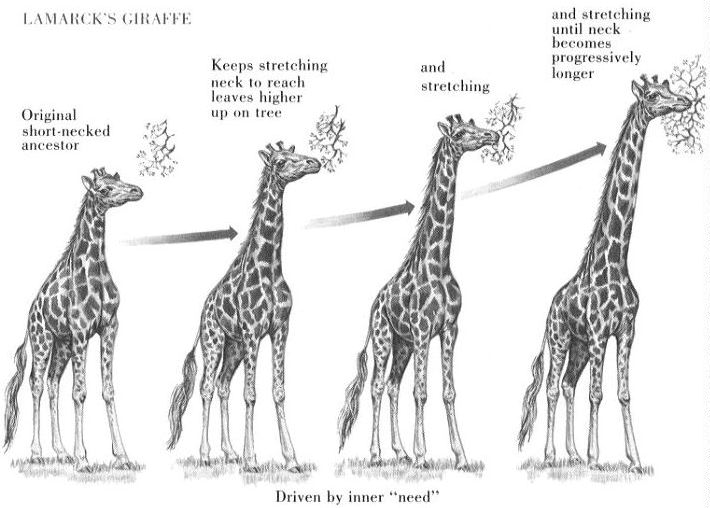
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**Unit 8, Part 2 Notes: Theories of Evolution and Evidence for Evolution**

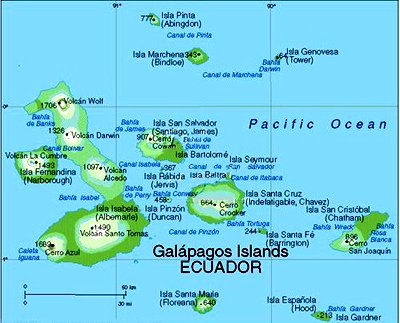
Pre-AP Biology, Mrs. Krouse

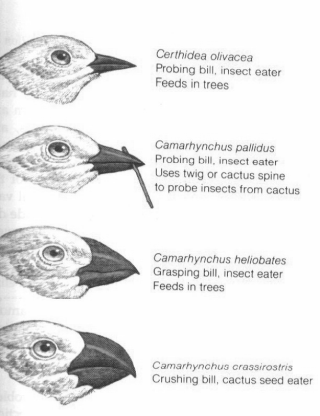
**1. What is evolution, and what causes evolution?**

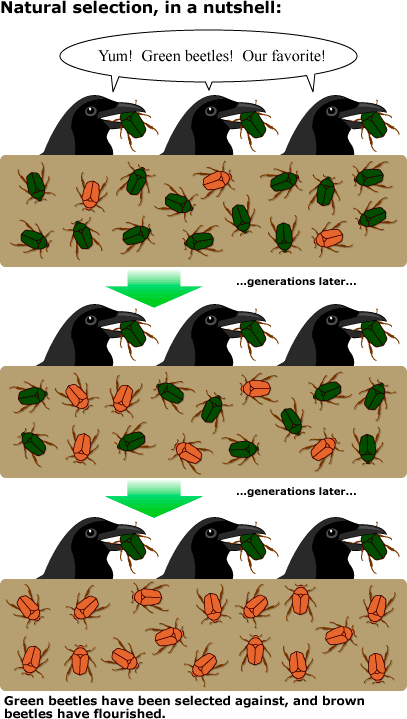
1. **Evolution** is defined as a change in the frequency of traits in a population over time (over generations).
2. A **population** is a group of organisms of the same species living in a particular area (ex: all the red-cockaded woodpeckers in a forest).
3. Remember, **genes** provide the code for traits **(phenotypes**). If evolution is a change in trait frequencies over time, then it is also a change in gene frequencies over time.
4. There are several scientists who developed theories about the cause of evolution. We will learn about two of these scientists—**Jean Baptiste Lamarck** and **Charles Darwin**—and their theories.
5. Lamarck proposed several hypotheses to describe the cause of evolution. These hypotheses are described below.
6. **Tendency Toward Perfection:** Organisms constantly change and gain features that make them more successful in their environment. For example, Lamarck proposed that the ancestors of birds acquired an “urge” to fly, and over time, their front limbs morphed into wings.
7. **Use and Disuse**: Body parts that get used by an organism become larger and stronger. Unused parts become smaller and eventually disappear.
8. **Inheritance of Acquired Characteristics:** Modifications or changes to an organism’s traits that are acquired throughout that organism’s lifetime can be passed down to that organism’s offspring.
9. In summary, Lamarck suggested that organisms constantly try to “improve” and modify their traits (ex: body parts) so they are more successful in their environment. This effort causes changes in traits. These changes can be passed down to future generations. As such, over time, the most useful traits become more common in the population.
10. Lamarck used these theories to explain the evolution of long necks in giraffes. He suggested that the necks of modern giraffes are long because ancestor giraffes had to stretch their necks to reach for food. This resulted in a permanent lengthening of their necks that was passed down to their offspring.



1. Today, we know that there are several issues with Lamarck’s theory. We know that certain traits (ex: increased muscle mass) can be acquired during an organisms lifetime, but these traits cannot be passed down to offspring. These traits cannot be passed down because they are not controlled by genes (DNA). Remember, in humans, genes are passed to offspring when the sperm created by a man fertilizes the egg created by a woman to create a zygote. A zygote will develop into an embryo and later a baby.
2. Charles Darwin was a geologist and biologist who sailed to various parts of South America (including the Galapagos Islands) on a ship called the H.M.S. Beagle. During his travels, he recorded observations of exotic plants and animals for the Queen of England. One of the groups of animals he observed were species of finches (little birds) on the Galapagos Islands. He noticed that finch species on the different islands consumed different types of food sources (ex: nuts, seeds, insects, etc.) He also noticed that finch species on the different islands had beaks that were different sizes and shapes. He proposed that these different beak sizes and shapes evolved by a process he called **natural selection**.



1. Darwin’s theory of natural selection has several components. These components are listed below…
2. There is variation in traits among organisms in a population. This is due to variations in genes that occur as a result of **mutation**. Remember, mutations can be beneficial to an organism, not affect an organism (neutral), or harmful to an organism.
3. Some variations of traits (determined by mutations) are favorable in a particular environment. For example, thicker fur would be a favorable trait in a very cold environment.
4. More offspring are produced in each generation than can survive. Organisms must compete for access to resources. Organisms with the most favorable traits compete more effectively and survive. Organisms with less favorable traits do not survive.
5. Organisms that survive go on to reproduce. Their favorable traits get passed down to the next generation and become more common. As such, the frequency of favorable traits increases over time. The population **adapts** as favorable trait frequencies increase.

*Note: A single organism cannot adapt because it cannot change its inherited traits, but it can possess* ***adaptations****. Adaptations are inherited traits that happen to be favorable in a particular environment.*

1. Many people equate Darwin’s theory of evolution by natural selection with the phrase “**survival of the fittest**.” This is a bit misleading because fitness requires more than just survival. To be fit means an organism must be able to survive AND reproduce. Fitness can be defined as an organism’s genetic contribution to the next generation (i.e., the number of offspring that the organism creates that carry its genes.)

***Practice Question #1:*** Determine which scientist would have agreed with the following statements.

|  |  |
| --- | --- |
| **Statement** | **Who thought this: Darwin, Lamarck or Both?** |
| 1. Organisms have changed over time. |  |
| 1. Organisms changed because they wanted to survive. |  |
| 1. Certain inherited traits helped organisms survive and reproduce better than other organisms without those traits. |  |
| 1. The environment had something to do with why the organisms changed. |  |
| 1. Parents are able to pass on traits they acquired during their lifetime to their offspring. |  |
| 1. Parents are only able to pass on traits that they were born with. |  |
| 1. Organisms could decide to change something about their body and pass that change onto their offspring. |  |
| 1. Single organisms cannot change their inherited traits, but the frequency of a trait within a population of organisms can change over time. |  |

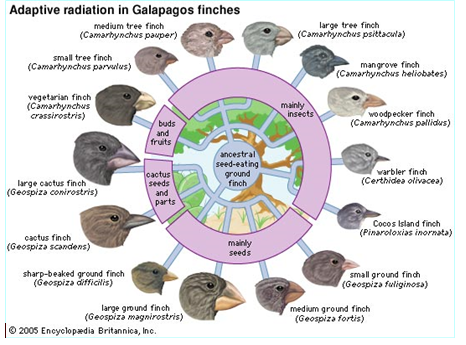
**2. What evidence do we have that evolution takes place?**

**Observations of Evolution in Currently-Living Species:**

1. We have actually observed evolution in some species. Remember, evolution is just a change in gene/trait frequencies in a population over generations.
2. One example of a species that we have directly observed evolving is the peppered moth. Peppered moths are native to England, and there are two color varieties—light and dark (see pictures given below).



1. Before the Industrial Revolution in England in the 19th century, light-colored moths were more common in the population. They camouflaged better than dark moths on the light tree bark and were less likely to be eaten by birds. As such, they survived and reproduced better than the dark moths.
2. During the Industrial Revolution, the trees became covered in soot from coal-burning factories. Dark moths were then better able to camouflage on the soot-covered trees than light moths. They were less likely to be eaten by birds, so they survived and reproduced better than the light moths. Because of this, the dark moths became more common in the population.
3. During the Industrial Revolution, the soot on the trees would be considered a “**selection pressure**” on the peppered moth population. A selection pressure is a factor in the environment that makes organisms with certain traits more likely to survive and reproduce than others.

***Practice Question #2:*** Researchers have found evidence that the many species of finches Darwin observed on the different Galapagos Islands evolved from a single ancestral finch species that ate seeds. Members of this ancestral population spread to the various islands. What selection pressure did they encounter on the islands, and how did this selection pressure cause evolution in the finches?

***Practice Question #3:*** Can a single finch change its beak size or shape? Why or why not? Use the term “favorable mutation” in your response.

**Fossil Evidence**

1. We also have evidence for evolution (evidence that populations of organisms have changed over time) in the **fossil record**.
2. A **fossil** is a trace of a long-dead organism that is typically found in layers of sedimentary rock. In the process of fossil formation, hard minerals typically replace the tissues of the organism’s body. Several types of fossils are described below.
3. A **mold** is an imprint of an organism’s body in rock.



1. A **cast** is a mold filled with hard minerals that takes the shape of the organism.
2. A **trace fossil** is any sign of life from an organism like a footprint or a burrow hole.



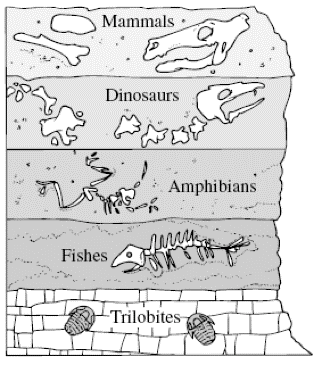


1. A **resin fossil** is an organism that has been preserved in hardened plant resin, which is called amber.
2. **Living fossils** are current species that very closely resemble their fossilized ancestors. Examples of living fossils are horseshoe crabs and velvet worms.

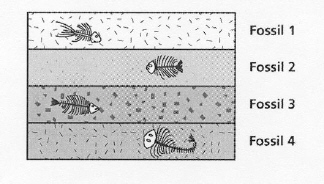
 

1. In the fossil record, there are many **transitional fossils**, which are organisms with intermediate characteristics between two species. Transitional fossils are evidence of a change (evolution) in the species from an ancestral form to a different modern form.
2. An example transitional fossil is *Archeopteryx*, which has both reptilian and avian (bird) characteristics and represents a transition from reptile ancestors to modern birds (see images given below of the actual fossil specimen and an artist’s rendering of this organism).

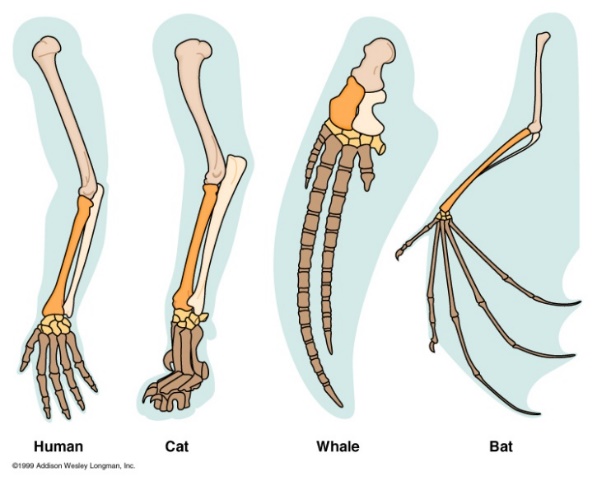
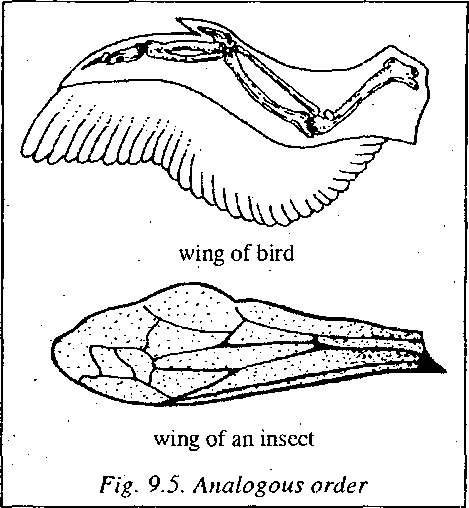
1. Scientists use two main methods determine the age of a fossil—relative dating and absolute dating.
2. **Relative dating** involves estimating the age of a fossil based on its position in layers of sedimentary rock. Older layers are buried deeper (lower) down, whereas newer layers are closer to the surface (higher up). With relative dating, scientists may use **index fossils**. Index fossils must be easily recognized as a particular species, and this species must have existed for a short time period across a large geographic range. Because they existed for a short time period, they are found only in a small number of rock layers. Because we know the age of these index fossils, we can approximate the age of fossils found in rock layers above and below these index fossils.
3. **Absolute dating** involves determining the exact age of a fossil. Absolute dating can also be called **radioactive dating** or **radiometric dating**. One type of absolute dating is **radiocarbon dating** (also known as **carbon-14 dating** or simply **carbon dating**). Radiocarbon dating is described below.

* Carbon-14 (C-14) is a **radioactive isotope** of carbon that has eight neutrons and is present in a living organism.
* After the organism dies, the carbon-14 undergoes a process called **radioactive decay** in which it breaks down into a non-radioactive isotope of nitrogen (specifically nitrogen-14, which has seven neutrons). Nitrogen-14 (N-14) then escapes into the air.
* Carbon-12 (C-12) is a non-radioactive isotope of carbon that has six neutrons and is present in a living organism.
* After the organism dies, carbon-12 does NOT break down. Thus, the amount of C-12 remains constant as the dead organism fossilizes.
* By comparing the amounts of C-14 (which goes down as it decays into N-14) and C-12 (which stays constant) scientists can determine when the organism lived. If there is a higher C-12 : C-14 ratio, this means the fossilized sample is older. If there is a lower C-12 : C-14 ratio, this means the fossilized sample is less old.
* Radioactive elements (ex: C-14) break down at a constant rate that is measured in a unit called a **half-life**. A half-life is the amount of time required for half of the radioactive atoms within a sample to decay. In other words, after one half-life has passed, only 1/2 of the radioactive atoms in the sample remain. After a second half-life, only 1/4 of the radioactive atoms in the sample remain. After a third half-life, only 1/8 of the radioactive atoms in the sample remain, and so on.
* C-14 has a half-life of 5730 years. This is a short half-life, so C-14 is only useful for dating fossils younger than 60,000 years old. If the fossil is older than this, the amount of C-14 remaining in the fossil would be difficult to detect or measure.
* For older fossils, researchers use radioactive elements with longer half-lives.

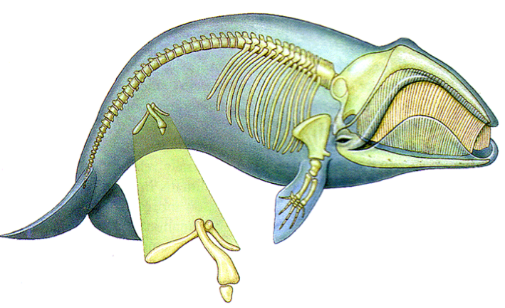
***Practice Question #4:*** Compare the relative ages of Fossil 2 and Fossil 3 using the image of sedimentary rock layers given to the right.

***Practice Question #5:*** How old is a fossil if only 1/32 of the original amount of C-14 remains? (Remember, the half-life of C-14 is 5730 years.)

**Evidence from Comparative Anatomy:**

1. **Comparative anatomy** involves comparing the body structures of different species. Similarities in body structures between species fall into two main types—homologous structures and analogous structures.
2. **Homologous structures** are similar structures found in different species that were inherited from a recent common ancestor of the species. These structures have changed in the different species as they evolved to adapt to different environments. For example, the same basic bone pattern is found in the limbs of many mammals (see image to the right) because this bone pattern was found in a **recent common ancestor** of these mammals. However, the limb bones have changed over time in each species due to different environmental requirements. For instance, human finger bones are structured such that they have the ability to grasp objects. Whale finger bones are long to provide support for fins used for swimming.
3. **Analogous structures** are similar structures found in different species that were NOT inherited from a recent common ancestor. These structures are similar because the species evolved to adapt to similar environments. For example, the wing of a bird and the wing of an insect have a similar shape because they are both used for flight. Birds and insects do not have a recent common ancestor.

**Evidence from Vestigial Structures**

1. **Vestigial structures** are organs or other body parts that were useful in the ancestor of a species but are no longer useful due to changing environmental requirements. As such, they are typically much smaller than a functional organ or body part.
2. For example, whales actually have a small pelvis (hip bones) that does not connect to rest of their skeleton. This pelvis probably connected to hind limbs (legs) in the land-living ancestor of whales. It is no longer useful because whales live in the water, so they do not need hind limbs for walking.
3. Examples of vestigial structures in humans are our appendix and short tailbone. Both of these structures do not have a major function in modern humans. However, larger versions of these structures may have had a function in the ancestor of modern humans.
4. In summary, vestigial structures provide evidence that species’ body parts have changed over time in response to changing environmental requirements. As such, vestigial structures provide evidence that these species have evolved.

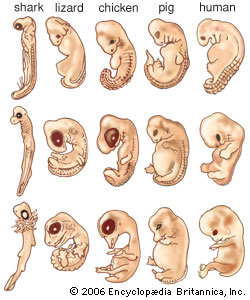
***Practice Question #6***: For each of the statements give below, circle the term that correctly completes the statement.

1. Homologous structures have a similar/different function.
2. Homologous structures can be found in organisms that are related/not related and have adapted to similar/different environments.
3. Analogous structures have a similar/different function.
4. Analogous structures can be found in organisms that are related/not related and have adapted to similar/different environments.
5. Vestigial structures in an organism have no purpose/an important purpose.
6. Vestigial structures in an organism are increased/reduced in size.

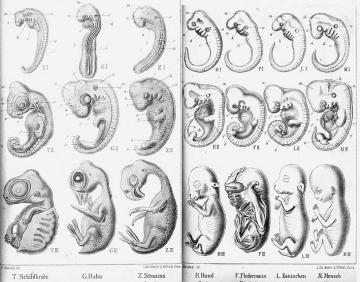
***Practice Question #7:*** For each of the structures described below, indicate whether the structures are homologous, analogous, or vestigial.

1. Wings on a flightless bird.
2. The fins of a shark (descended from a fish ancestor) and a dolphin (descended from a mammalian ancestor).
3. Eyes on a fish that lives in complete darkness.
4. Bird wings and reptile limbs. (Birds and modern reptiles descended from a recent common reptilian ancestor.)

**Evidence from Comparative Embryology**



1. **Comparative embryology** involves comparing the **embryos** (early developmental forms) of animals with a backbone.
2. Scientists have found that the embryos of many vertebrates (organisms with a backbone) are very similar in their structure (see image to the right). As such, these embryos provide evidence that these different vertebrate species evolved from a common ancestor.
3. A scientist named Ernst Haeckel studied comparative embryology and drew images of the embryos of several vertebrate species. Some of his drawings contained inaccuracies and made the earliest stages of some embryos seem more similar than they actually are. In science slang, we would say that he “fudged his data.” Some of his drawings are shown below.



***Practice Question #8:*** According to the image shown to the right of a), b), and c) above, do humans share a more recent common ancestor with chickens or sharks? Explain your answer.

**Evidence from Comparative Biochemistry:**

1. **Comparative biochemistry** involves comparing the DNA, RNA, or protein sequences found in the cells of species.
2. If more similarities exist in the nitrogen base sequences of DNA or RNA or the amino acid sequences of proteins between two species, then these species are more closely related. This means they share a recent common ancestor. Similarities in these sequences are called **molecular homologies**.
3. If fewer similarities exist in the nitrogen base sequences of DNA or RNA or the amino acid sequences of proteins between two species, then these species are less closely related. This means they do not share a recent common ancestor. Instead they share an **older/more ancient/more distant common ancestor.**

***Practice Question #9:*** According to the DNA sequences given below, are pigs more closely related to humans or crickets? Explain your answer.

